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Older Workers and the Adoption of New Technologies

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Non-technical Summary

Given the demographic development, which is characterized by an increasing life expectancy and a simultaneous decrease in birthrates, the age structure of the working population has been changing. The employment rate of individuals between 55 and 64 years has increased, particularly during the last five years, whereas the employment rate of individuals between 15 and 24 years has decreased in the same time period.

In an economy where knowledge is one of the important production factors and information processing is based on information and communication technologies (ICT), an efficient relationship between human capital and ICT usage is crucial for the successful performance and competitiveness of firms. As several studies show that older workers are less likely and less qualified to use ICT compared to younger employees, the question whether firms of the ICT-intensive service sectors with a high share of older workers are less likely to adopt new technologies arises. The results of this paper show that firms with a higher share of younger employees are more likely to adopt new technologies, and that the older the workforce is, the less likely is the adoption of new technologies.

Previous studies find a complementary relationship between the use of ICT and modern human resource practices. Furthermore, the use of innovative workplace practices may provide a better environment for the adoption of new technologies. On the other hand, there is some empirical evidence that innovative workplace practices are negatively related to the employment of older workers. Since innovative workplace practices seem to have adverse relationships with ICT and new technologies on the one hand and the employment of older workers on the other hand this paper closes a research gap by analyzing the joint impact of the age of the workforce and the enhancement of teamwork as well as the flattening of hierarchies as a tools of workplace organization on the probability of adopting new or significantly improved technologies. The results show that firms which have enhanced their teamwork or flattened their hierarchies and have a higher share of employees being younger than 30 years are less likely to adopt new or significantly improved technologies whereas firms that enhanced their teamwork or flattened their hierarchies and have a higher share of workers aged between 40 and 55 years are more likely to adopt new technologies.

Zusammenfassung

Aufgrund der durch einen Anstieg der Lebenserwartung und einen gleichzeitigen Rückgang der Geburtenrate gekennzeichneten demografischen Entwicklung hat sich die Altersstruktur der arbeitenden Bevölkerung verändert. So ist die Beschäftigungsquote der 55-64-jährigen insbesondere in den vergangenen fünf Jahren angestiegen, während gleichzeitig ein Rückgang der Beschäftigungsquote der 15-24-jährigen erfolgt ist.

In einer Volkswirtschaft, in der Wissen ein wichtiger Produktionsfaktor ist und Informations- und Kommunikationstechnologien (IKT) zur Verarbeitung von Informationen benötigt werden, ist eine effiziente Verzahnung von Humankapital und IKT für den Erfolg und die Wettbewerbsfähigkeit von Unternehmen entscheidend. Mehrere Studien belegen, dass die Wahrscheinlichkeit der Anwendung von IKT bei älteren Arbeitnehmern geringer ausgeprägt ist als bei jüngeren Arbeitnehmern, und erstere hierfür auch weniger qualifiziert sind. Daher stellt sich die Frage, ob Unternehmen aus IKT-intensiven Dienstleistungssektoren, die einen hohen Anteil an älteren Beschäftigten haben, eine geringere Wahrscheinlichkeit des Einsatzes neuer Technologien aufweisen. Die Ergebnisse der vorliegenden Arbeit zeigen, dass Unternehmen, die einen höheren Anteil an jüngeren Beschäftigten haben, eine höhere Wahrscheinlichkeit aufweisen, neue Technologien einzusetzen. Je älter die Belegschaft eines Unternehmens ist, desto geringer ist dessen Wahrscheinlichkeit neue Technologien einzusetzen.

Laut vorherigen Studien besteht ein komplementärer Zusammenhang zwischen der Nutzung von IKT und der Anwendung moderner Methoden der Personal- und Arbeitsorganisation. Des Weiteren kann durch die Anwendung innovativer Methoden der Arbeitsorganisation möglicherweise ein günstigeres Umfeld für den Einsatz neuer Technologien geschaffen werden. Auf der anderen Seite gibt es empirische Evidenz dafür, dass die Anwendung innovativer Methoden der Arbeitsorganisation mit der Beschäftigung älterer Arbeitnehmer negativ korreliert ist. Da die Anwendung innovativer Methoden der Arbeitsorganisation eine gegensätzliche Beziehung mit der Anwendung von IKT und neuen Technologien einerseits und mit der Beschäftigung älterer Arbeitnehmer andererseits zu haben scheint, wird mit dieser Arbeit eine Forschungslücke geschlossen, da die gemeinsame Auswirkung von Alterstruktur der Belegschaft und Verstärkung der Gruppenarbeit sowie Abflachung der Hierarchien als Methoden der Arbeitsorganisation auf die Wahrscheinlichkeit des Einsatzes neuer oder wesentlich verbesserter Technologien untersucht wird. Die Ergebnisse zeigen, dass Unternehmen, die Gruppenarbeit verstärkt oder Hierarchien abgeflacht haben und einen höheren Anteil an unter 30-jährigen beschäftigen, eine geringere Wahrscheinlichkeit aufweisen, neue bzw. wesentlich verbesserte Technologien einzuführen; wohingegen Unternehmen, die Gruppenarbeit verstärkt oder Hierarchien abgeflacht haben und einen größeren Anteil an 40-55-jährigen beschäftigen, eine höhere Wahrscheinlichkeit des Einsatzes neuer Technologien aufweisen.

Older Workers and the Adoption of New Technologies

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Abstract: For the first time data of German ICT and knowledge intensive service providers are used to analyze the relation between the age structure of the workforce and the probability of adopting new technologies. The results show that firms with a higher share of younger employees are more likely to adopt new technologies and the older the workforce the less likely is the adoption of new technologies. Furthermore the results exhibit that the age structure of the workforce should be accompanied by appropriate workplace organization. A part of the firms which enhanced teamwork or flattened their hierarchies are actually more likely to adopt new technologies and software when they have a higher share of older employees whereas they are less likely to introduce new technologies if they have a higher share of younger employees.

Keywords: age structure of the workforce, adoption of new technologies, ICT intensive services
JEL-Classification: J14, O31

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1 Introduction

In the face of the demographic development, characterized by an increasing life expectancy and a simultaneous decrease in birthrates, the age structure of the working population is observably changing. The employment rate of individuals between 55 and 64 years has increased particularly in the last five years. In the EU-25 the employment rate of this age group has increased by 5.9 percent from 2000 to 2005 and amounted to about 42 percent in 2005. The employment rate of individuals between 15 and 24 years has decreased by about 1.3 percentage points in the same time period (Eurostat 2007a). In Germany the employment rate of individuals between 55 and 64 years reaches a level of about 45 percent in the year 2005 (see Figure A.1 in the appendix). Several studies show that compared to younger employees older workers are less likely and less qualified to use information and communication technologies (ICT) (e.g. de Koning and Gelderblom 2006, Schleife 2006). In an economy that is marked by rapid technological progress, the demographic development on the one hand and the relationship between older workers and ICT on the other hand provide a great challenge for the firms. Especially for firms belonging to ICT intensive and human capital intensive sectors an efficient relationship between these two factors is crucial for the successful development of those sectors.

In particular, this is the case for knowledge intensive service providers (e.g. tax consultancy and accounting, architecture) and for information and communication technology service providers (e.g. telecommunication services, software and IT services). These sectors contribute to about eight percent of the sales in the German Economy (Statistisches Bundesamt 2006). These industries exhibit two main characteristics that have determined their economic performance. First, structure, quality and organization of human capital inside the firms are exceptionally important aspects in the production of the services they provide. Second, they make an intensive use of ICT, relying on a continuous adoption of new technologies and software. Considering the previous empirical results concerning the relationship between older workers and ICT it can be hypothesized that firms of the mentioned industries engaging older workers are less likely to adopt new or significantly improved technologies than firms of these industries with a younger workforce.

This paper analyzes this hypothesis by focussing on the relationship between the age structure of the workforce and the adoption of new technologies of ICT and knowledge intensive service providers. Thereby it takes into account other factors that may affect the likelihood of the adoption of new technologies or software. The analyses are based on a data set of 362 German firms from the IT-related services sector. The paper also analyzes the robustness of the results by testing different specifications. The empirical results show that firms with a higher share of younger employees are more likely to adopt new technologies and the older the workforce the less likely is the adoption of new technologies. Besides the age of the workforce, the customer requirements and the introduction of product innovations also impact the adoption of new or significantly improved technologies and software.

Previous studies find a complementary relationship between the use of ICT and modern human resource practices, such as team work and performance-related wages (Bresnahan, Brynjolfsson, and Hitt 2002, Bertschek and Kaiser 2004). This discussion is mainly related to decentralising organisational measures implying more involvement of employees in decision making processes and more responsibilities of employees. Furthermore, there is some empirical evidence, that the share of older workers is lower in firms with applied innovative workplace practices (Beckmann 2001, Aubert, Caroli, and Roger 2006). Related to these findings the impact of an interaction between changes in the workplace organization and the age structure of the workforce on the probability of adopting new technologies is analyzed. The results show that a specific age structure of the workforce should be accompanied by appropriate workplace organization. Firms that flattened their hierarchies, enhanced their teamwork and have a higher share of employees being younger than 30 years are less likely to adopt new or significantly improved technologies. By contrast firms that changed their workplace organisation and have a higher share of employees between 40 and 55 years are more likely to adopt new technologies. This result however only holds for some of the firms, depending on their predicted probability to adopt new technologies.

This paper is organised as follows. The second section reviews the background discussion in existing economic literature on the relation between older workers, ICT, technology adoption and workplace organisation. Subsequently follow a description of the used data, the 46th wave of the quarterly business survey among IT-related service providers conducted by the Centre for European Economic Research (ZEW) and some descriptive statistics. In the fourth section the estimation strategy and the empirical results are presented. Section five concludes and gives an outlook on further demands on research.

2 Background Discussion

This paper focuses on the relationship between the age structure of the workforce and the adoption of new or significantly improved technologies or software in ICT and knowledge intensive service providing firms. Therefore it is related to several strands of the literature.

There is the literature on older workers and ICT. Furthermore, as the adoption of new technologies in the IT-related services sectors can be seen as a process innovation,[1] the literature on older workers and process innovations is also concerned. There are several studies using individual data that show that compared to younger employees older workers are less likely and less qualified to use ICT. Friedberg (2003) analyzes the relationship between computer use at work and the age of the workers using individual data on American workers in the year 1993. Her results reveal, that workers younger than 60 years use a computer more often than workers older than 60 years. Using individual-level data from 1997 of German male workers Schleife

[1] According to the Oslo Manual (OECD, Eurostat 2005), "a process innovation is the implementation of a new or significantly improved production or delivery method". This includes significant changes in equipment, techniques and/or software (OECD, Eurostat 2005). The firms of these service industries are not inventing or creating new processes. As Hempell (2003b) states, the service providing firms, especially those of the knowledge intensive branches rely on the inputs of the industry. So a process innovation is a change in the process of creating services, caused by the introduction of new technologies or software, provided by the industry or other service providers.

(2006) finds that the probability of computer use among workers aged between 55 and 64 years is significantly lower than that of workers between 25 and 34 years. Borghans and ter Weel (2002) and de Koning and Gelderblom (2006) show in their analyses that the computer skills of younger employees are better than those of older workers. De Koning and Gelderblom (2006) additionally exhibit that the probability of using complicated ICT applications at work is lower among workers above 50 years. Other papers analyze the reverse effect, thus how does the use of IT or the adoption of new technologies affect the share of older workers. Bertschek (2004) shows in her analysis with German firm level data that the higher the IT-intensity, the lower the share of employees being 50 years or older. There is only weak empirical evidence for the opposite. Beckmann (2001) finds that a firm which has invested in IT leads to positive impacts on the employment of older workers. He measures ICT usage by using a dummy variable for ICT investments. This dummy variable, however, does not reflect to what extent the employees are affected by the corresponding investment in ICT.

The literature on the so called age-biased technological change using firm-level data finds that technological progress negatively impacts the share of older workers or older low-skilled workers (Behaghel and Greenan 2007). Aubert, Caroli, and Roger (2006) examine the impact of innovations on the wage-bill share of workers from different age groups in France. They find that the wage-bill share of older workers (aged 50 years and above) is lower in innovative firms, i.e. innovative firms tend to be biased against age. Beckmann (2005) finds that technological change has a negative impact on the share of older employees in West German firms. Schneider (2007) uses a linked employer-employee approach to analyze the impact of the age structure of the workforce on product innovations of German manufacturing firms. He finds signifcant effects of the age structure of the workforce on the technological innovativeness and an inverse u-shaped age innovation profile. There are only few empirical investigations, that analyze the relation between process innovation and the age of the workforce in manufacturing firms. Rouvinen (2002) analyzes the characteristics of product and process innovations in the Finnish manufacturing sector. He finds, that an increasing average employee age, although he uses this variable as proxy for firm age, reduces the probability of process innovation. Another analysis that examines the relation between innovation and the age of the workforce is the one from Nishimura, Minetaki, Shirai, and Kurokawa (2004). They investigate the interaction between age and qualification of the employees and its impact on technological progress in Japanese industries. They only have a small sample and find no significant impact of old workers (above 40 years) with high qualification (share of old workers with high education to the total labor inputs) on the rate of technological progress in non-manufacturing industries. But they find that the share of old workers with high qualification in the 1990s reduces the rate of technological progess in the manufacturing industries.

The relationship between technological change and ICT on the one hand and older workers on the other hand is explained by two main hypotheses: (1) Using two data sets from the U.S., Friedberg (2003) states that the more infrequent use of computers amongst older workers is related to the imminent retirement. Investment in computer skills does not pay off any longer.

She finds that computer users tend to retire later than non-users probably due to comparative advantages and because they are ready to invest in training. Furthermore, her results reveal that the more infrequent use of computers amongst older workers can be explained by the differences across occupations and education. Empricial evidence for Germany by Schleife (2006) suggests that age does not play a significant role for the retirement decision when controlling for other factors such as qualification, work experience, etc. Borghans and ter Weel (2002) even find that the imminent retirement of older workers is no significant parameter affecting the disuse of computers. The discussion about technological change and the retirement decision is related to the vintage human capital models (MacDonald and Weisbach 2004). Within technological change and innovation human capital may become obsolete. So older workers may offer resistance to innovation when their human capital might be ridden off. (2) Weinberg (2004) argues from a different point of view. He states that the ability to learn how to use a computer declines with increasing age. This is in line with the so called "deficit-model" that explains the process of aging from a gerontological point of view. This model assumes that older people compared to younger ones loose important features, they show defects and deficits. This affects physical (fading physical strength or decelerated reactions) and psychic skills (cutback of brainpower, especially of fluid brainpower which is the one needed amongst others for new solutions and a fast processing of informations (Börsch-Supan, Düzgün, and Weiss 2005)) as well as constricted interests and reduced social activities (Walter 1995). This can be referenced to the economic context and the labor market. Asked what kind of attributes emerge in which age group and how important those features are, personnel officers reply that skills like learning aptitude, willingness to learn or flexibility can be less found by older workers compared to younger ones (Boockmann and Zwick 2004). These skills, however, are especially important for the implementation of process innovation in terms of adopting new technologies or software.

There is a broad literature suggesting that the implementation of new IT systems often goes hand in hand with organizational changes in firms. Therefore, IT investment and organizational investment are interpreted as strategic complementarities (Brynjolfsson and Hitt 2000, Bresnahan, Brynjolfsson, and Hitt 2002, Bertschek and Kaiser 2004). This discussion is mainly focussed on decentralizing organizational measures implying more involvement of employees in decision making processes and more responsibilities of employees. Some examples are team work, flat hierarchies, autonomous working groups or incentive pay - measures supposed to positively affect the information flow within firms and the motivation of the employees. The use of innovative workplace practices such as teamwork and flat hierarchies (Gera and Gu 2004, Webster 2004) may provide a better environment for the adoption of new technologies because of the existing complementarities (Milgrom and Roberts 1990, Hitt and Brynjolfsson 1997, Bresnahan, Brynjolfsson, and Hitt 2002). The implementation of a new information and communication or software system often requires a restructuring of the firm to use the new system efficiently. Thus, it appears likely that workplace reorganization has to be changed accordingly to make the operating process more efficient. But the other way round, it is also possible, that the introduction or enhancement of teamwork and the flattening of hierarchies may have an impact on the probability of introducing new technologies or software.

Taking into account the complementary relationship between ICT and workplace organization, there is also some empirical evidence on the relationship between older workers and organizational structures. These studies find that innovative workplace practices giving more decision-making authority and responsibility to employees is negatively related to the employment of older workers. Using West German firm level data for the years 1993 to 1995 Beckmann (2001, 2005) finds that organizational changes have significantly negative effects on the precentage share of workers aged 50 or more. Aubert, Caroli, and Roger (2006) provide empirical evidence for France using linked employer-employee data. They find that the more innovative workplace practices are applied in the firm the lower is the percentage share of older workers. But not only the internal organization may affect the probability to introduce new technologies or software, but also the external environment of the firm. The market and customers with their requirements (de Jong, Bruins, Dolfsma, and Meijaard 2003) and the competitive situation may result in the need to introduce new technologies or software to keep up with the surrounding development.

3 Data and Descriptive Statistics

The data used for the empirical analyses is taken from the quarterly business survey among the "service providers of the information society" conducted by the Centre for European Economic Research (ZEW) in cooperation with the credit rating agency Creditreform. The sector "service providers of the information society" comprises nine industries belonging to the information and communication technology service providers (e.g. software and IT services) and the knowledge-intensive service providers (e.g. tax consultancy and accounting).[2] Every quarter a single-page questionnaire is sent to about 3,500 mostly small- or medium-sized firms. At each wave, the survey achieves a response rate of about 25%. It is a random sample, stratified with respect to company size, region and sector affiliation. The questionnaire is divided into two parts. In the first part, firms assess their current business development with respect to the previous quarter as well as their expectations for the next quarter. The second part is dedicated to questions concerning current economic issues, ICT diffusion or particular information about the firms e.g. their innovative activities or training behavior. The questions of the second part change quarterly with selected questions being repeated annually. The survey is designed as a panel.[3] This paper mainly uses the data of the 46th wave (3rd quarter 2005). Some informations also have been taken from the 45th, 48th and 49th wave. The final dataset includes 362 firms.[4]

Former waves of the data have previously been used to analyze the productivity effects of organizational change (Bertschek and Kaiser 2004) and the relationship between managerial ownership

[2]For further details on the nine industries, their industrial classification and their distribution within the sample see the appendix and Table A.1 in the appendix.

[3]Although the question concerning the technology adoption has been asked for the fourth time, panel data estimations cannot be provided. The survey among "service providers of the information society" is a very versatile data set where firms take part on an irregular basis. The use of the panel data causes a great loss of observations and unobserved heterogeneity could not be taken into account because there is only a very tiny fraction of firms for which data are available for more than two periods in a row.

[4]For the composition of the used sample and further details see the appendix.

and firm performance (Mueller and Spitz-Oener 2006).

The adoption of new or significantly improved technologies and software is represented by a dummy variable.[5] The share of employees in four age groups (younger than 30 years, between 30 and 40 years, between 40 and 55 years and older than 55 years) are used to analyze how the age of the workforce affects the adoption of new technologies or software.[6] In a second step, interactions between these age groups and a change in the workplace organization are provided to test whether complementarities exist.[7]

Table 3.1 shows some descriptive statistics of the data, comparing those firms that adopted new or significantly improved technologies in the last twelve months to those firms that did not. Most of the employees are older than 30 years and younger than 55 years. About 57.6 percent of the employees of those firms that adopted new technologies are younger than 40 years compared to about 51.5 percent of the employees of the firms that did not adopt new technologies. The share of older workers is higher in firms that did not adopt new technologies. As Table 3.1 shows, about 36 percent of the employees in firms not having adopted new technologies are between 40 and 55 years old compared to 32.8 percent of the employees of firms that adopted new technologies. The share of employees being 55 years and older is about 12.5 percent in the firms that did not adopt new or improved technologies compared to about 9.6 percent in the firms with technology adoption.

Table 3.1: Descriptive statistics

feature	firms that adopted new technologies	firms that did not adopt new technologies	total sample
share of employees below 30 years	24.9%	19.1%	22.1%
share of employees between 30 and 40 years	32.7%	32.4%	32.6%
share of employees between 40 and 55 years	32.8%	36.0%	34.3%
share of employees above 55 years	9.6%	12.5%	11.0%
share of highly qualified employees	37.9%	36.9%	37.4%
flattening of hierachies	34.5%	23.4%	29.2%
enhancement of teamwork	48.5%	31.2%	40.2%
changed customer requirements	80.0%	55.2%	68.2%
foreign competitors	59.2%	46.6%	53.1%
firm size (number of employees)	122.2	34.3	80.0
exporters	35.7%	34.5%	35.1%

Source: ZEW, own calculations

Comparing firms that adopted new or significantly improved technologies to those that did not adopt new technologies one can see that there is nearly no difference between them in terms of the share of highly qualified employees, in particular 37.9 percent compared to about 36.9 percent (see Table 3.1). This seems striking as there has been a lot of discussion in the skill-biased technological change literature (e.g. Chennells and van Reenen 2002, Card and DiNardo 2002),

[5]The firms answered the following question: Did you adopt new or significantly improved technologies in the last 12 months (e.g. new electronic data processing systems, Internet)?

[6]The share of employees being younger than 25 years and being between 25 and 30 years old have been combinded to the group younger than 30 years.

[7]A list of the variables used and some summary statistics can be found in Table A.2 in the appendix.

suggesting that the use of new technologies and the diffusion of IT change the skill requirements (Autor, Levy, and Murnane 2003, Spitz-Oener 2006) and thus lead to an increase in demand for highly qualified labour (see for instance Falk (2002) for the case of Germany).

Table 3.1 reveals that amongst firms that adopted new technologies the share of firms whose workplace organization changed (enhancement of teamwork and flattening of hierachies) in the last three years is higher than amongst firms that did not adopt new technologies. On the one hand, this can be a signal for the generally higher propensity to change and innovate in certain firms. On the other hand it reflects the complementary relationship between ICT and workplace organization.

More than half of the firms that adopted new technologies is competing with foreign firms, whereas this share is lower among the firms that did not adopt new or significantly improved technology as Table 3.1 shows. About 80 percent of the firms that adopted new technologies report changed customer requirements in the last three years, just more than half of the firms that did not adopt new technologies had to face changed customer requirements.

The exporting activities between the two types of firms differ only slightly. About 35.7 percent of the firms that adopted new or improved technologies in the last twelve months are exporting services abroad, but only 34.5 percent of the firms that did not adopt new technologies are doing so. Moreover, larger firms are adopting new technologies rather than smaller firms. Those firms that adopted new technologies or software in the last twelve months have on average about 122 employees, whereas firms that did not adopt new technologies have only about 34 employees on average.

The descriptive analysis of the data also shows, that the adoption of new or significantly improved technologies varies across industries. Firms belonging to the software and IT services branch are the ones, that mostly adopted new technologies. Slightly more than 65 percent of these firms introduced new technologies or software within the last twelve months. Firms belonging to the research and development sector, however, are rarely adopting new technologies, about 35 percent report to have adopted new or significantly improved technologies (see Figure A.2 in the appendix).

4 Empirical Analysis

4.1 Estimation Strategy

In the following, the hypothesis that firms with a higher share of older workers are less likely to adopt new or significantly improved technologies is analyzed. The variable measuring the decision to adopt new or significantly improved technologies and software is a dummy variable and has the following form:

$$\text{technology adoption} = \begin{cases} 1 & \text{if the firm adopted new technologies} \\ 0 & \text{if the firm did not.} \end{cases}$$

Thus, the impact of several independent variables on a dichotomous dependent variable will be examined.[8]

$$prob(technology\ adoption = 1) = F(\alpha + \beta age + \gamma X + \delta controls + \epsilon) \quad (1)$$

where $prob(\cdot)$ is the probability that a firm adopts a new or significantly improved technology, β is a coefficient vector that describes the impact of four different age groups of employees. The coefficient vector γ shows the effects of several other firm and market characteristics, δ represents a vector of coefficients regarding controls such as sector dummies and a dummy variable for East Germany and ϵ is the unobservable error term. A Probit model is used, assuming the error term ϵ is normally distributed.

The impact of each age group on the probability of adopting new technologies is estimated seperately. Additionally, all four age groups are estimated altogether, taking the group of employees below 30 years as the reference group. To check the robustness of the results, four different specifications are taken into account. In specification (1) besides the age structure and the controls, the share of highly qualified employees and dummy variables for the firm size are considered.[9] Additionally, in specification (2), the firm age, a dummy variable for exporting activity and a dummy variable for foreign competition are regarded. Older firms may be more traditional than their younger counterparts and therefore less inclined to change the operating process. Exporters may depend on the latest communication technologies in order to stay in contact with their customers abroad. In specification (3) dummy variables for changes in the workplace organization (enhancement of teamwork and flattening of hierarchies) and a change in the customer and market requirements within the last three years are added. The share of employees working predominantly with a computer measures the IT-intensity of the firm. This share and a dummy variable for product innovation are additionally considered in specification (4). The introduction of a product innovation may lead to a change in the operating process and therefore to the adoption of new technologies.[10]

Taking into account the relationship between ICT and workplace organization as well as between workplace organization and older workers, in a second step, the interaction between the age groups and a change in the workplace organization is taken into account. As the magnitude of the interaction effect in a Probit model does not equal the marginal effect of the interaction term, the method proposed by Ai and Norton (2003) and Norton, Wang, and Ai (2004) is used.[11] In

[8] All calculations and estimations of this paper have been done with STATA 9.1.

[9] Bigger firms may profit from emerging economies of scale.

[10] Note however, that there may be some endogeneity problems. The age of the workforce may be endogenous, but at this stage, it is assumed that the age of the workforce is a constant factor, that doesn't significantly change within twelve months. Moreover, the dummy variable for product innovation may be endogenous, but the data doesn't provide appropriate instruments to control for this endogeneity.

[11] Only specification (4) is used to estimate the impact of the interaction effects between the age groups and the workplace organization.

a Probit model, the magnitude of a interaction effect requires computing the cross derivative or cross difference of the expected value of the dependent variable. When one continuous and one dummy variable are interacted with each other the interaction effect is the discrete difference (with respect to the dummy variable) of the single derivative (with respect to the continuous variable). Using their method, the interaction effect is found by computing the cross derivatives (or differences). The standard error of the interaction effect is computed by applying the Delta method. The test for statistical significance has to be based on the estimated cross-partial derivative.

4.2 Results

The estimation results can be found in Tables A.3 to A.6 in the appendix. As the estimated coefficients in a Probit model only allow to make a statement on the significance and the sign of an effect but not on the extent, only the marginal effects are discussed in the following. Table 4.1 reports the average marginal effects of the four age groups in the Probit estimations of the four different specifications. However, the results only reveal correlations and no causal relationships. It can be seen that firms with a higher share of employees being younger than 30 years have a higher probability to adopt new technologies, whereas firms with a higher share of employees being older than 55 years have a lower likelihood to introduce new or significantly improved technologies. The results also reveal that the older the workforce, the less probable the adoption of new or significantly improved technologies.

In particular, an increase in the share of employees below 30 years by one percent is related to an increase in the probability of adopting new technologies by 0.40 percentage points (see second column of Table 4.1, specification (1)). This result holds for all four specifications and the marginal effect lies between 0.40 and 0.53. This may be due to two reasons. Workers below 30 years have a high productivity and a high potential concerning the mastery of equipment and software (Tijdens and Steijn 2005). Moreover, the knowledge of this age group may still be up to date as their educational attainment has been achieved recently.

The likelihood of adopting new technologies and software is related to a decrease of 0.43 percentage points in the likelihood of adopting new technologies if the share of employees being older than 55 years increases by one percent (see fifth column of Table 4.1, specification (1)). This finding is robust as the effect is valid for all four specifications. The marginal effect is between 0.43 and 0.51. There is also a negative relationship between the share of employees between 40 and 55 years and the likelihood of adopting new technologies although this effect is only significant in the second and fourth specification and even there only at the ten percent significance-level.

Table 4.1: Marginal effects of Probit estimations

Variable	**marg. effect (std. error)**	**marg. effect (std. error)**	**marg. effect (std. error)**	**marg. effect (std. error)**	**marg. effect (std. error)**
			(1)		
share of employees below 30 years	0.399***				reference
	(0.141)				categorie
share of employees between 30 and 40 years		-0.005			-0.323*
		(0.141)			(0.174)
share of employees between 40 and 55 years			-0.151		-0.339**
			(0.130)		(0.157)
share of employees above 55 years				-0.429**	-0.617***
				(0.217)	(0.232)
			(2)		
share of employees below 30 years	0.478***				reference
	(0.141)				categorie
share of employees between 30 and 40 years		0.042			-0.345*
		(0.151)			(0.179)
share of employees between 40 and 55 years			-0.242*		-0.446***
			(0.138)		(0.159)
share of employees above 55 years				-0.514**	-0.715***
				(0.225)	(0.237)
			(3)		
share of employees below 30 years	0.446***				reference
	(0.153)				categorie
share of employees between 30 and 40 years		-0.011			-0.350*
		(0.156)			(0.192)
share of employees between 40 and 55 years			-0.195		-0.407**
			(0.140)		(0.169)
share of employees above 55 years				-0.507**	-0.714***
				(0.233)	(0.250)
			(4)		
share of employees below 30 years	0.531***				reference
	(0.169)				categorie
share of employees between 30 and 40 years		0.007			-0.405*
		(0.173)			(0.214)
share of employees between 40 and 55 years			-0.235*		-0.512***
			(0.142)		(0.180)
share of employees above 55 years				-0.483*	-0.745***
				(0.265)	(0.277)

Significance levels : $*$: 10% $**$: 5% $***$: 1%

The last column of Table 4.1 contains the result of estimating all four age groups together. Compared to the share of employees below 30 years an increase in the share of employees being older than 30 years is related to a decrease in the probability of adopting new or significantly improved technologies, whereas the older the workforce the less likely is the adoption of new technologies or software. Table 4.1 shows that the probability to adopt new technologies is related to a decrease of 0.32 percentage points if the share of employees between 30 and 40 years decreases by one percent compared to the share of employees below 30 years (specification (1)). An increase in the share of employees between 40 and 55 years by one percent lowers the probability of introducing new technologies and software by about 0.34 percentage points (specification (1)). An increase in the share of workers older than 55 years by one percent, compared to the share of workers below 30 years, is related to a decrease of 0.62 percentage points in the likelihood of the adoption of new technologies or software (specification (1)). This result is robust as it holds for all four specifications.

An older staff hence is negatively related to the likelihood of introducing new or significantly improved technologies in the operating process. This is partly in line with the finding of Schneider (2007) who finds an inverse u-shaped age innovation profile in the manufacturing sector. Furthermore, the results support the empirical evidence found by Rouvinen (2002) and Nishimura, Minetaki, Shirai, and Kurokawa (2004). They also find a negative influence of older employees on the (process) innovation probability in the manufacturing industries. This issue may be explained by two different hypotheses. Firstly, it may be that older workers have more problems to adopt to changes in the operating process, especially when they have a longer tenure. This is supported by the "deficit-model" mentioned before and by the study of Morris and Venkatesh (2000). This effect could be boosted by the kind of changes, if especially new technologies or software cause problems for older workers as stated by e.g. de Koning and Gelderblom (2006) and Schleife (2006) or Borghans and ter Weel (2002), who find that employees being older than 30 years have lower ICT-skills. Secondly, older firms which mainly employ older workers with longer job tenure may be more traditional itself and therefore less inclined to innovate or to change the working routine at all. This explanation, however, can be excluded, as the firm age is only to a certain extent related to the probability of adopting new technologies (see Tables A.4 and A.5 in the appendix). Only in the last specification firm age has a positive significant effect on the likelihood of adopting new technologies for all age groups (see Table A.6 in the appendix). Firms that are older are more likely to adopt new or significantly improved technologies. One reason for this may be that newly founded firms start with the latest technology. Another reason could be that older firms have more capital and are therefore more likely to invest in new technologies.

Besides the age of the workforce the adoption of new or significantly improved technologies is simultaneously affected by some other factors. The analysis however reveals that not all of the variables controlled for are significant. It can be seen that the firm size positively affects the probability of adopting new technologies, although only in some of the specifications (see Tables A.3 - A.6 in the appendix). Firms with more than nine employees are more likely to adopt new technologies (see Tables A.3 - A.6 in the appendix). This can be explained by emerging economies of scale. The larger the firm, the cheaper the introduction of new technologies or software per employee. Another point may be decreasing training costs, as the adoption of new technologies or software involves training requirements (Hempell 2003a).

Furthermore, changed customer requirements positively affect the probability of adopting new or significantly improved technologies. Firms that had to face changed market or customer requirements within the last three years are more likely to adopt new technologies (see Tables A.5 and A.6 in the appendix). This result seems plausible since the provision of knowledge intensive services and ICT services comes along with a high degree of interaction with clients and customers respectively (Koch and Strotmann 2006). On the other hand, the firms analyzed in this study are mostly small and medium sized firms. De Jong and Brouwer (1999) find in their literature review that the customer information and a close cooperation with them is one of the main sources for (product) innovation in SMEs. As, especially in the service sector, a change in the operating process through new methods (in this case especially new information and communication technologies) may lead to improved services, the influence of the customer requirements is indispensable.

The enhancement of teamwork in the last three years as a tool of workplace organization is positively related to the probability of adopting new technologies at the firm-level (see Table A.5 in the appendix). This is partly in line with empirical analyses that arrive at the conclusion that the workplace organization matters in the context of innovation probability. Webster (2004) or Zoghi, Mohr, and Meyer (2007) for example find that the extent of innovation, i.e. the probability of innovation, is higher in firms that have a stronger communication between management and workers or decentralized structures and information-sharing. The same conclusions are drawn by Gera and Gu (2004), who show that measures beyond information-sharing programs like human resource management practices, including self-directed work groups (teamwork) significantly enhance the probability of introducing process innovations. However, the effect of enhanced teamwork turns to be insignificant if the dummy variable presenting product innovation is considered (see Table A.6 in the appendix). This suggests that in general innovative firms also tend to be innovative regarding their workplace organization. The flattening of hierarchies however has no significant effect on the probability of adopting new technologies or software (see Tables A.5 and A.6 in the appendix).

The introduction of product innovations is positively related to the likelihood of adopting new technologies and software. Firms that offer new services are more likely to adopt new technologies (see Table A.6 in the appendix). On the one hand, this can be explained by a generally higher willingness of the firm to innovate or renew the operating process itself. On the other hand, in the services sector product innovations and process innovations can't be distinguished easily. A process innovation, as the adoption of new or significantly improved technologies, allows to improve the quantity or quality of a provided service by keeping the input constant, reducing the supply costs or accelerating the process (Hempell 2003b). This change in the provided service, caused by a process innovation, is in turn interpretable as product innovation. The data don't offer apropriate instruments to control for endogeneity or simultaneity problems arising in this context.

Table A.7 in the appendix shows the interaction effects between changes in the workplace organization and the share of employees belonging to one of the four age groups, their standard errors and their z-statistics, computed by the method of Ai and Norton (2003) and Norton, Wang, and Ai (2004) instead of using the standard STATA output. The interpretation of the interaction effect is based on figures A.3 and A.4 in the appendix, as the interaction effect, the standard errors and the z-statistic are calculated for each observation.[12] For each interaction effect two graphs are presented. The first graph plots two interaction effects (one is calculated by the method of Norton, Wang, and Ai (2004), and the other one is calculated by the conventional linear method) against predicted probabilities and the second graph of each interaction effect plots the z-statistics against predicted probabilities.

As the upper left graph in Figure A.3 shows, firms with a higher share of younger workers and an enhancement of teamwork in the last three years are less likely to adopt new technologies as firms that did not enhance teamwork. This effect is lower for firms whose probability to adopt new technologies or software is rather low or rather high in absolute terms and higher for firms whose probability to adopt new technologies or software lies between 0.2 and 0.8. The effect however is only significant for the latter firms, as can be seen in the upper right graph in Figure A.3. Regarding the interaction between the enhancement of teamwork and the share of employees between 40 and 55 years, the interaction effect is reverse. Firms that enhanced teamwork in the last three years and have a higher share of employees between 40 and 55 years are more likely to adopt new technologies compared to firms that did not enhance teamwork. This effect is higher for firms whose probability to adopt new or significantly improved technologies is about 0.5 (see lower left graph in Figure A.3 in the appendix). Nevertheless, only few of the firms that have a predicted probability to adopt new technologies between 0.25 and 0.75 have statistically significant effects, as can be seen in the lower right graph in Figure A.3 in the appendix.

With respect to the flattening of hierarchies in the last three years, a similar picture is drawn. Firms that flattened their hierarchies and have a higher share of employees below 30 years are less likely to adopt new technologies compared to firms without a change in the workplace organization. This effect is higher for firms whose predicted probability to adopt new technologies is around 0.5 and smaller for firms whose predicted probability is rather high or low, as we can see in the upper left graph in Figure A.4 in the appendix. But this effect is only significant for those firms whose predicted probability is between 0.15 and 0.85, as the upper right graph in Figure A.4 in the appendix shows. The effect of the share of employees between 40 and 55 years in firms that flattened their hierarchies is also reverse. As we can see in the lower left graph in Figure A.4 in the appendix, firms that flattened their hierarchies and have a higher share of workers being between 40 and 55 years old are more likely to adopt new technologies

[12]Only the significant effects are reported.

and software than firms that did not flattened their hierarchies. This effect is higher for those firms whose predicted probability is around 0.5 and lower for those whose predicted probability is rather low or high. Nevertheless, here the effect is only significant for some of those firms whose predicted probability is between 0.3 and 0.7 as the lower right graph in Figure A.4 in the appendix shows.

The empirical results show that the age structure of firms has to be combined with appropriate workplace organizations in order to keep up with the technological development. A part of the firms with a higher share of younger workers and innovative workplace practices are less likely to adopt new technologies and some firms with a higher share of workers between 40 and 55 years and enhanced teamwork and flattened hierarchies have a higher probability to adopt new technologies. At first sight this seems to contradict former empirical evidence from the manufacturing sector. It finds that workplace reorganization is negatively related to the proportion of older employees in firms (e.g. Beckmann 2005, Aubert, Caroli, and Roger 2006) and therefore suggests that older employees and innovative workplace practices are no suitable match. However, the results presented here are considering service sector firms instead of firms belonging to the manufacturing sector. The classification of the age groups differs. Beckmann (2005) or Aubert, Caroli, and Roger (2006) find the negative effect for workers being 50 years or older whereas here it is the group of employees between 40 and 55 years that is positively linked with teamwork. Furthermore, firms that are very likely or very unlikely to adopt new technologies are not affected by the joint impact of enhanced teamwork and workers being younger than 30 years or between 40 and 55 years respectively. And this is also the interesting point in this result. It suggests that only those firms that are not determined in adopting new technologies or in not adopting them from the beginning can increase their probability to adopt new technologies by taking the age structure and the appropriate workplace organization in terms of teamwork into account. As technology adoption is a key factor in staying competitive the results suggest that firms with a high share of employees being younger than 30 years should abstain from enhancing teamwork or flattening hierarchies whereas firms with a high proportion of employees between 40 and 55 years should enhance teamwork or flatten hierarchies.

5 Conclusion

Due to the demographic development the workforce is getting older. As older people appear to be less likely and less qualified to use ICT, the age structure of the workforce may have an impact on the efficiency of the adoption of new or significantly improved technologies and software. In particular this may be the case for industries that are ICT intensive, relying on the continuous adoption of new technologies or software.

Using a cross-sectional data set of 362 firms of the German ICT and the knowledge intensive service providers in the year 2005 this paper finds that the age structure of the workforce is negatively related to the probability of adopting new or significantly improved technologies and software. Firms with a higher share of younger employees are more likely to adopt new technologies. This is in line with the literature that analyses the impact of the age of the employees on the probability of technological change and innovations in the manufacturing industries. The results reveal that firms with a higher share of employees being younger than 30 years have a higher probability to adopt new technologies, whereas firms with a higher share of employees being older than 55 years have a lower likelihood to introduce new technologies or software. After comparing the four age groups it becomes clear that the older the workforce, the less likely is the adoption of new technologies or software.

The use of innovative workplace practices may provide a better environment for the adoption of new technologies and the relationship between ICT and workplace organisation is complementary. Therefore, the interaction between the share of employees below 30 years and the share of employees between 40 and 55 years, the flattening of hierarchies and the enhancement of teamwork is analysed. The results exhibit contrary effects. Firms that flattened their hierarchies, enhanced their teamwork and have a high share of younger workers are less likely to adopt new technologies than firms that did not change their workplace organisation. Firms that changed their workplace organisation and have a higher share of employees between 40 and 55 years are more probable to adopt new technologies compared to firms without workplace reorganisation. It seems that firms with a certain age structure of the workforce need appropriate workplace organisation to keep up with the technological development. This result, however, is only significant for some firms in the sample depending on their predicted probability to adopt new technologies.

Finally, the analyses show that there are further factors affecting the adoption of new or significantly improved technologies and software such as the change of market or customer requirements and the introduction of product innovation.

As the cross-sectional data offer no appropriate instruments to control for potential endogeneity of the age of the workforce as well as of the endogeneity of the introduction of product innovations, future research shall focus on this caveat. Analysing the relationship between the age structure of the workforce and the adoption of new technologies and software by using a panel data set could also help to control for unobserved heterogeneity in this context.

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A Appendix

The ZEW quarterly business survey among service providers of the information society includes the following industries (codes of the German Classification of Economic Activities, Edition 2003 in parentheses): software and IT services (71.33.0, 72.10.0-72.60.2), ICT-specialized trade (51.43.1, 51.43.3-3.4, 51.84.0, 52.45.2, 52.49.5-9.6), telecommunication services (64.30.1-0.4), tax consultancy and accounting (74.12.1-2.5), management consultancy (74.11.1-1.5, 74.13.1-3.2, 74.14.1-4.2), architecture (74.20.1-0.5), technical consultancy and planning (74.20.5-0.9), research and development (73.10.1-73.20.2) and advertising (74.40.1-0.2). Table A.1 shows, how the industries are distributed in the sample.

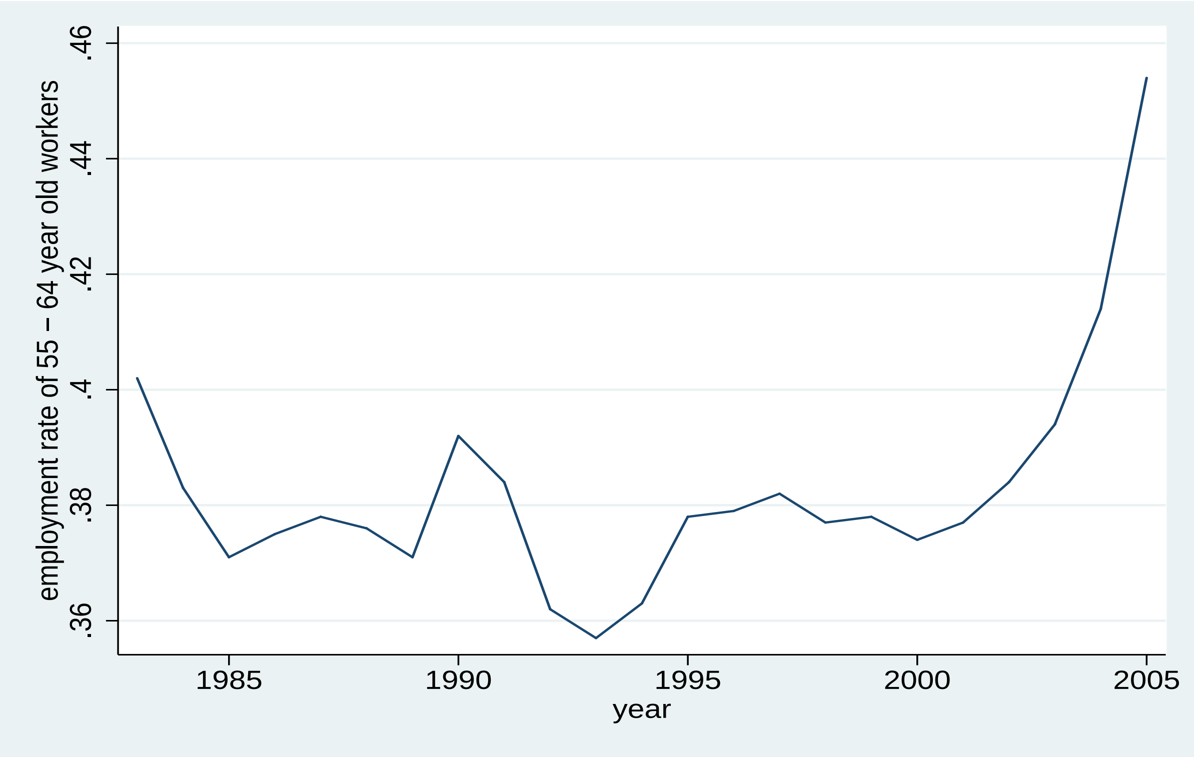
Table A.1: Distribution of industries in the sample

Industry	Percentage
software and IT services	9.39
ICT specialized trade	17.40
telecommunication services	3.87
tax consultancy and accounting	17.13
management consultancy	8.56
architecture	13.81
technical consultancy and planning	11.88
research and development	11.88
advertising	6.08
sum	100

Source: ZEW, own calculations

It contains mostly small- or medium-sized firms. In the composed sample the biggest firm has about 1,033 employees. The 46th wave of the survey, used here, includes information on the age structure of the workforce, the qualification level of the employees, the implemented process, product and organizational innovations, the export activity and foreign competitors. As the survey is constructed as a panel, gaps can be filled with data from other waves. The number of employees is created from the information on the age structure and the qualification level of the employees from the 46th wave. The information on the share of employees working predominantly with a computer (IT-intensity) is taken from the 45th, 48th and 49th wave.

Figure A.1: Development of the employment rate of 55 - 64 year old workers



Source: Eurostat (2007b)

Figure A.2: Share of firms that adopted new technologies by sectors

Source: ZEW, own calculations

Table A.2: Summary Statistics

Variable	**Number of observations**	**mean**
process innovation	362	0.5193
product innovation	324	0.5031
share of employees below 30 years	362	0.2209
share of employees between 30 and 40 years	362	0.3258
share of employees between 40 and 55 years	362	0.3434
share of employees above 55 years	362	0.1098
share of highly qualified employees	362	0.3743
enhancement of teamwork	326	0.4018
flattening of hierarchies	325	0.2923
customer requirements	324	0.6821
firm size 1-9 employees	362	0.2790
firm size 10-19 employees	362	0.2624
firm size 20-49 employees	362	0.2127
firm size more than 50 employees	362	0.2459
firm age	356	16.0225
foreign competitors	335	0.5313
exporter	353	0.3513
IT-intensity	362	0.7781
(share of employees working predominantly with a computer)		
East Germany	362	0.2541

Source: ZEW, own calculations

Table A.3: Results of Probit estimation (1)

dependent variable: dummy for adoption of new technologies					
Variable	**coefficient (Std. Err.)**	**coefficient (Std. Err.)**	**coefficient (Std. Err.)**	**coefficient (Std. Err.)**	**coefficient (Std. Err.)**
share of employees below 30 years	1.033***				reference
	(0.384)				categories
share of employees between 30 and 40 years		-0.014			-0.859*
		(0.367)			(0.469)
share of employees between 40 and 55 years			-0.395		-0.901**
			(0.343)		(0.426)
share of employees above 55 years				-1.129*	-1.642**
				(0.579)	(0.634)
share of highly qualified employees	0.125	0.008	-0.002	0.005	0.102
	(0.270)	(0.268)	(0.267)	(0.267)	(0.273)
firm size (dummy variable=1 if 1-9 employees)		reference categorie			
firm size (dummy variable=1 if 10-19 employees)	0.193	0.248	0.237	0.174	0.150
	(0.186)	(0.185)	(0.185)	(0.190)	(0.191)
firm size (dummy variable=1 if 20-49 employees)	0.211	0.314	0.278	0.242	0.174
	(0.205)	(0.201)	(0.203)	(0.206)	(0.210)
firm size (dummy variable=1 if 50 or more employees)	0.269	0.365*	0.334*	0.289	0.230
	(0.196)	(0.192)	(0.085)	(0.196)	(0.199)
East Germany	-0.054	-0.078	-0.058	-0.075	-0.054
	(0.168)	(0.168)	(0.168)	(0.169)	(0.168)
industry dummies jointly significant	no	no	no	no	no
Intercept	-0.536	-0.260	-0.122	-0.116	0.488
	(0.327)	(0.320)	(0.332)	(0.318)	(0.428)
N	362	362	362	362	362
Log-likelihood	-238.332	-241.862	-241.218	-239.871	-237.484
$\chi^2_{(14)}$	24.227	16.457	18.053	20.503	
$\chi^2_{(16)}$					25.357

Significance levels: * : 10% ** : 5% *** : 1% heteroscedasticity-robust standard errors

Table A.4: Results of Probit estimation (2)

dependent variable: dummy for adoption of new technologies					
Variable	**coefficient (Std. Err.)**	**coefficient (Std. Err.)**	**coefficient (Std. Err.)**	**coefficient (Std. Err.)**	**coefficient (Std. Err.)**
share of employees below 30 years	1.230***				reference
	(0.400)				categorie
share of employees between 30 and 40 years		0.112			-0.945*
		(0.400)			(0.497)
share of employees between 40 and 55 years			-0.648*		-1.221***
			(0.374)		(0.451)
share of employees above 55 years				-1.380**	-1.957***
				(0.618)	(0.673)
share of highly qualified employees	0.111	-0.082	-0.065	-0.077	0.053
	(0.307)	(0.304)	(0.304)	(0.302)	(0.310)
firm size (dummy variable=1 if 1-9 employees)			reference categorie		
firm size (dummy variable=1 if 10-19 employees)	0.321	0.363*	0.362*	0.277	0.263
	(0.201)	(0.201)	(0.200)	(0.207)	(0.206)
firm size (dummy variable=1 if 20-49 employees)	0.206	0.336	0.290	0.259	0.159
	(0.223)	(0.218)	(0.220)	(0.224)	(0.229)
firm size (dummy variable=1 if 50 or more employees)	0.150	0.270	0.224	0.185	0.095
	(0.216)	(0.212)	(0.214)	(0.215)	(0.221)
firm age	0.014*	0.011	0.013	0.013	0.015*
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
exporter	0.008	0.023	0.042	-0.015	-0.007
	(0.171)	(0.168)	(0.170)	(0.170)	(0.173)
foreign competitors	0.214	0.237	0.204	0.248	0.211
	(0.159)	(0.157)	(0.158)	(0.157)	(0.160)
East Germany	-0.133	-0.145	-0.121	-0.149	-0.124
	(0.188)	(0.188)	(0.188)	(0.189)	(0.189)
industry dummies jointly significant	no	no	no	no	no
Intercept	-1.018*	-0.682*	-0.433	-0.505	0.231
	(0.393)	(0.378)	(0.385)	(0.373)	(0.469)
N	325	325	325	325	325
Log-likelihood	-208.922	-213.749	-212.313	-211.225	-207.758
$\chi^2_{(17)}$	31.376	21.119	24.327	26.372	
$\chi^2_{(19)}$					33.277

Significance levels: * : 10% ** : 5% *** : 1% heteroscedasticity-robust standard errors

Table A.5: Results of Probit estimation (3)

dependent variable: dummy for adoption of new technologies					
Variable	**coefficient (Std. Err.)**	**coefficient (Std. Err.)**	**coefficient (Std. Err.)**	**coefficient (Std. Err.)**	**coefficient (Std. Err.)**
share of employees below 30 years	1.341***				reference
	(0.474)				(categorie)
share of employees between 30 and 40 years		-0.033			-1.059*
		(0.458)			(0.587)
share of employees between 40 and 55 years			-0.573		-1.229**
			(0.416)		(0.524)
share of employees above 55 years				-1.504**	-2.157***
				(0.701)	(0.776)
share of highly qualified employees	0.235	0.058	0.054	0.026	0.174
	(0.345)	(0.337)	(0.341)	(0.337)	(0.347)
firm size (dummy variable=l if 1-9 employees)			reference categorie		
firm size (dummy variable=l if 10-19 employees)	0.430*	0.457**	0.439*	0.376	0.373
	(0.234)	(0.231)	(0.234)	(0.239)	(0.237)
firm size (dummy variable=l if 20-49 employees)	0.332	0.455*	0.406*	0.400	0.304
	(0.251)	(0.244)	(0.246)	(0.249)	(0.254)
firm size (dummy variable=l if 50 or more employees)	0.059	0.156	0.100	0.074	0.005
	(0.245)	(0.236)	(0.241)	(0.239)	(0.250)
firm age	0.014*	0.011	0.013	0.013*	0.015*
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
exporter	-0.119	-0.102	-0.097	-0.151	-0.152
	(0.191)	(0.190)	(0.190)	(0.192)	(0.193)
foreign competitors	0.194	0.227	0.198	0.225	0.191
	(0.179)	(0.177)	(0.179)	(0.176)	(0.180)
flattening of hierarchies	-0.127	-0.149	-0.143	-0.159	-0.139
	(0.210)	(0.203)	(0.206)	(0.203)	(0.209)
enhancement of teamwork	0.368*	0.413**	0.407**	0.448**	0.401**
	(0.194)	(0.193)	(0.192)	(0.188)	(0.195)
customer requirement	0.800***	0.776***	0.778***	0.765***	0.789***
	(0.184)	(0.181)	(0.182)	(0.183)	(0.185)
East Germany	-0.053	-0.085	-0.071	-0.065	-0.039
	(0.210)	(0.209)	(0.208)	(0.212)	(0.210)
industry dummies jointly significant	no	no	no	no	no
Intercept	-1.695***	-1.251***	-1.057**	-1.087**	-0.357
	(0.458)	(0.435)	(0.447)	(0.426)	(0.560)
N	283	283	283	283	283
Log-likelihood	-166.198	-170.153	-169.267	-168.1	-165.292
$\chi^2_{(20)}$	62.115	50.623	51.726	56.919	
$\chi^2_{(22)}$					63.911

Significance levels: * : 10% ** : 5% *** : 1% heteroscedasticity-robust standard errors

Table A.6: Results of Probit estimation (4)

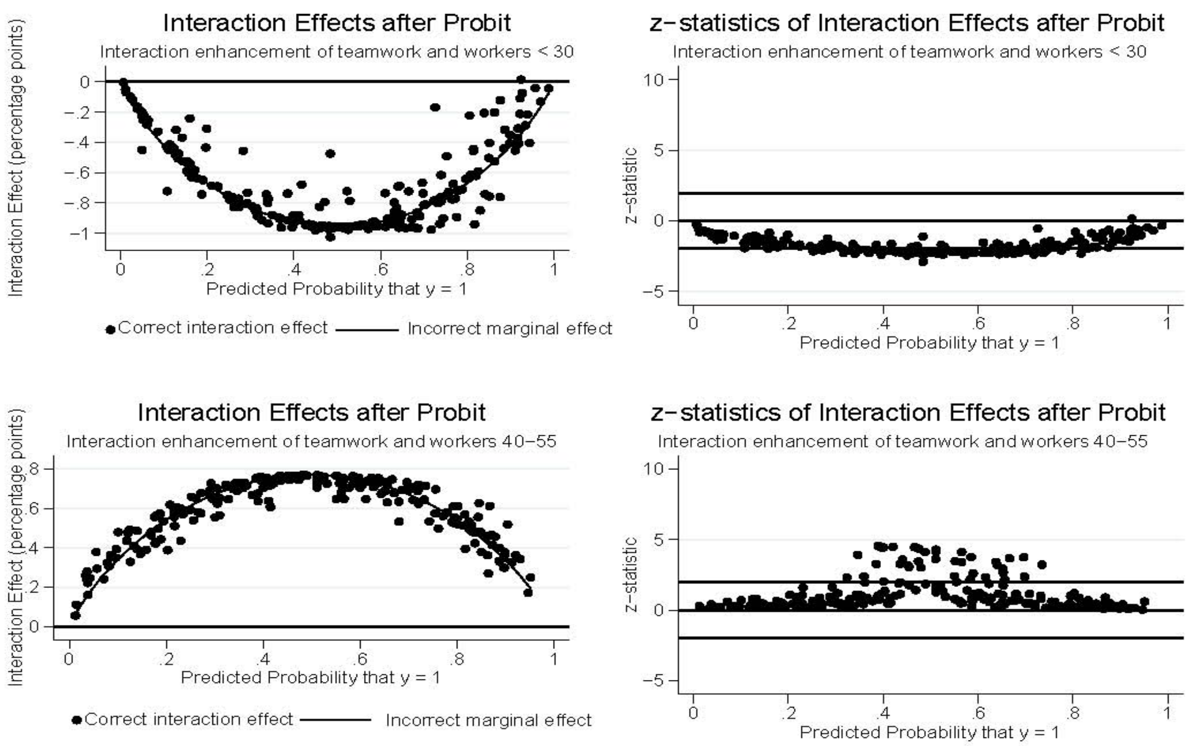
dependent variable: dummy for adoption of new technologies					
Variable	**coefficient (Std. Err.)**	**coefficient (Std. Err.)**	**coefficient (Std. Err.)**	**coefficient (Std. Err.)**	**coefficient (Std. Err.)**
share of employees below 30 years	1.757***				reference
	(0.575)				(categorie)
share of employees between 30 and 40 years		0.022			-1.347*
		(0.551)			(0.721)
share of employees between 40 and 55 years			-0.755*		-1.702***
			(0.458)		(0.611)
share of employees above 55 years				-1.565*	-2.475**
				(0.859)	(0.939)
share of highly qualified employees	0.230	-0.040	-0.016	-0.080	0.142
	(0.426)	(0.410)	(0.414)	(0.409)	(0.430)
firm size (dummy variable=1 if 1-9 employees)			reference categorie		
firm size (dummy variable=1 if 10-19 employees)	0.360	0.403	0.389	0.315	0.298
	(0.272)	(0.265)	(0.267)	(0.279)	(0.276)
firm size (dummy variable=1 if 20-49 employees)	0.498*	0.626**	0.592**	0.572*	0.474
	(0.295)	(0.285)	(0.286)	(0.293)	(0.297)
firm size (dummy variable=l if 50 or more employees)	0.070	0.185	0.145	0.111	0.027
	(0.295)	(0.285)	(0.289)	(0.289)	(0.298)
firm age	0.020**	0.015*	0.017**	0.017*	0.021**
	(0.009)	(0.008)	(0.009)	(0.009)	(0.009)
exporter	-0.071	-0.033	-0.039	-0.097	-0.114
	(0.219)	(0.216)	(0.216)	(0.220)	(0.221)
foreign competitors	-0.024	0.027	-0.003	0.027	-0.026
	(0.214)	(0.208)	(0.213)	(0.208)	(0.216)
flattening of hierarchies	-0.127	-0.131	-0.153	-0.159	-0.161
	(0.242)	(0.239)	(0.241)	(0.238)	(0.245)
enhancement of teamwork	0.026	0.099	0.094	0.145	0.074
	(0.225)	(0.228)	(0.223)	(0.221)	(0.230)
customer requirement	0.782***	0.685***	0.711***	0.672***	0.763***
	(0.217)	(0.217)	(0.220)	(0.217)	(0.220)
product innovation	0.874***	0.858***	0.863***	0.840***	0.862***
	(0.209)	(0.207)	(0.208)	(0.207)	(0.209)
IT - intensity	0.155	0.258	0.212	0.263	0.162
	(0.380)	(0.367)	(0.362)	(0.374)	(0.381)
East Germany	0.100	-0.008	0.044	0.028	0.132
	(0.258)	(0.251)	(0.251)	(0.254)	(0.259)
industry dummies jointly significant	no	no	no	no	no
Intercept	-2.135***	-1.595***	-1.313**	-1.358**	-0.363
	(0.598)	(0.573)	(0.571)	(0.584)	(0.722)
N	224	224	224	224	224
Log-likelihood	-120.598	-124.824	-123.702	-123.259	-119.972
$\chi^2_{(22)}$	75.682	57.303	61.972	63.562	
$\chi^2_{(24)}$					76.603

Significance levels: * : 10% ** : 5% *** : 1% heteroscedasticity-robust standard errors

Table A.7: Interaction effects

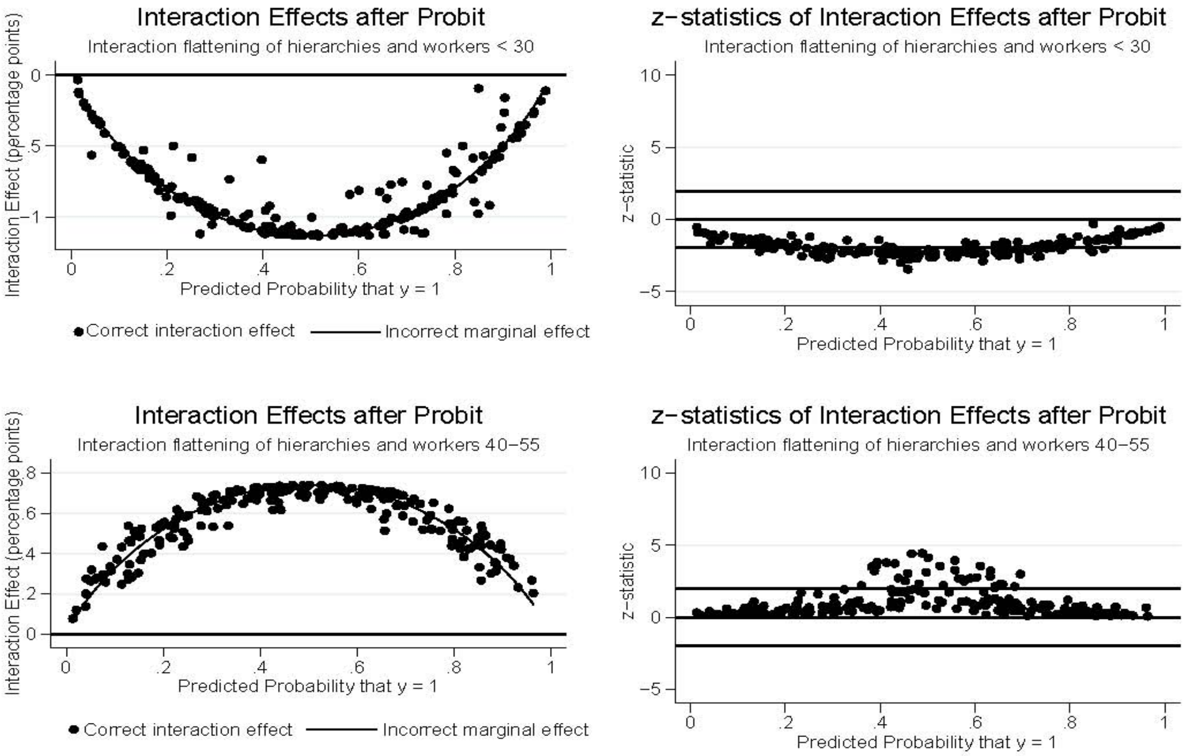
Variable	mean interaction effect	mean std. error	mean z-statistic
	interaction with teamwork		
share of employees below 30 years	-0.679	0.371	-1.735
share of employees between 30 and 40 years	0.190	0.398	0.660
share of employees between 40 and 55 years	0.595	1.097	1.102
share of employees above 55 years	-0.369	1.002	-0.627
	interaction with flat hierarchies		
share of employees below 30 years	-0.825	0.428	-1.884
share of employees between 30 and 40 years	0.042	0.165	0.263
share of employees between 40 and 55 years	0.569	1.085	0.997
share of employees above 55 years	0.334	0.755	0.727

Figure A.3: Interaction effects: enhancement of teamwork



Source: Own calculations based on estimation of specification (4), 234 observations

Figure A.4: Interaction effects: flattening of hierarchies



Source: Own calculations based on estimation of specification (4), 234 observations